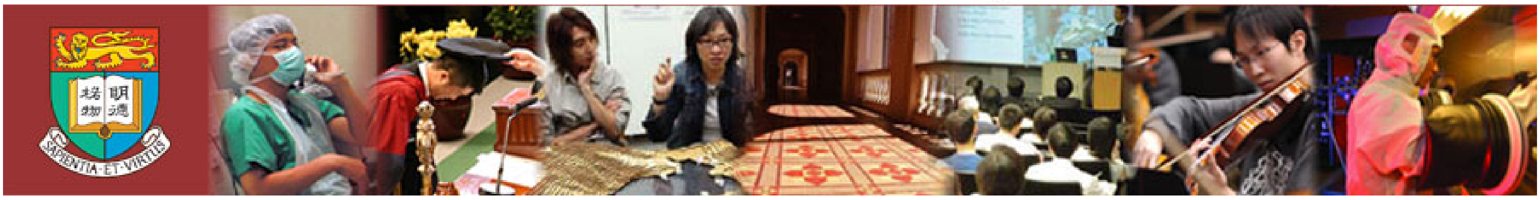

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Citation	
Issued Date	**2010**
URL	**http://hdl.handle.net/10722/173730**
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Effects of self-controlled feedback paradigm on motor learning of a "relaxed phonation" task

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A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, 30 June, 2010

ABSTRACT

The present study investigated the effects of self-controlled feedback paradigm on motor learning of a relaxed phonation task. Twenty-four vocally healthy individuals were randomly assigned into two groups: self-controlled feedback group (SELF) and clinician-controlled feedback group (YOKED). The participants were instructed to read aloud sentence stimuli. Surface electromyographic values (sEMG) measured at thyrohyoid site were provided as biofeedback. The SELF group received sEMG biofeedback whenever they requested, and the YOKED group received the same feedback schedule as chosen by their self-controlled counterparts. Results revealed significant reduction of muscle tension across training sessions. Generalization was shown to reading of untrained passage in both groups. However, the results failed to demonstrate differences between the SELF and YOKED groups. It provided no clear evidence to conclude the self-controlled feedback paradigm was beneficial to learning of relaxed phonation. The guidance hypothesis might have accounted for the absence of self-controlled learning effect in the study.

Keywords: Self-controlled learning, voice motor learning, surface electromyography (EMG)

INTRODUCTION

Hyperfunctional voice disorder is the most common voice disorder in the world (Andrews, 1996). According to Freeman and Fawcus (2001), it was caused by using excessive laryngeal muscle tension during phonation. It can significantly affect the quality of life of the individuals in emotions, occupation and communication aspects (Ma & Yiu, 2001). Among different treatment methods for hyperfunctional voice available in the field, relaxed phonation is often used as an effective treatment to reduce laryngeal muscle tension in this population (Ramig & Verdolini, 1998). Motor learning is involved in the voice training as the learner is required to learn or relearn new skills to facilitate relaxed phonation (Boone, McFarlane, & Von Berg, 2005). By definition, motor learning is “a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement” (Schmidt & Lee, 1999, pp.264). Therefore, it is critical to evaluate the effects of learning using retention test to ensure the temporary learning effects within training session which no longer interfere the long-term learning effect measured after training period (Magill, 1998; Schmidt & Lee, 1999).

Traditional voice training takes a clinician-directed approach. The clinician controls the practice variables (e.g., feedback schedule, practice condition) in the training process. The learner is relatively passive in the learning process as they have only minimal control in planning and controlling the practice variables throughout the training. Researchers have examined various factors that affect motor skill learning and one of them is learning with self-controlled feedback paradigm. Augmented feedback is defined as extrinsic information the learners receive about their performance on the task (Schmidt & Lee, 1999). It appears that feedback on performance is essentially important in guiding the learners to achieve the goal in motor learning. In self-controlled feedback paradigm, the learner has the control over the schedule of provision of feedback during training. In contrast to the self-controlled feedback paradigm, the learner under the clinician-controlled feedback paradigm (i.e., namely externally-controlled feedback paradigm in the sports motor learning studies) has no control over the scheduling of feedback. The feedback schedule is controlled by the clinician.

The literature has documented consistent findings that self-controlled feedback paradigm can lead to beneficial learning effects when compared to the clinician-controlled feedback paradigm in motor learning. Janelle, Kim and Singer (1995) first put forward to explain the role of cognitive effort on the learning benefits of self-controlled learning. Janelle and colleagues proposed that the learners were actively involved in the learning process when deeper and effective information processing of relevant information occurred in the self-controlled group (Janelle, et al., 1995; McCombs, 1989). The enhanced self-control in the learning process may also be attributed to the higher motivation to learn and perform in the group (Wulf & Toole, 1999). Furthermore, self-controlled learning is relatively tailored and more correspond to the learners' need (Chiviacowsky & Wulf, 2002). The motivation developed in self-controlled group motivates the learners to refine the skills for movement and explore different learning strategies to achieve performance goal. The motivational effect of self-controlled feedback enhanced learning (Wulf, 2007). In contrast, the yoked group has no control over feedback schedule in the practice, and therefore the amount of cognitive effort they invested in learning as well as the learning motivation would be reduced. Therefore, participants in the yoked group are not reinforced to engage in similar information-processing activities in the learning process. As practice proceeds, the skills learnt in the self-controlled group are better retained and this facilitates better performance in retention and transfer tests.

In the field of sports sciences, Janelle and colleagues have investigated the effects of self-controlled feedback paradigm on motor learning using ball-tossing task. In the study by Janelle et al. (1997), participants were required to perform non-dominant hand ball throw in two practice sessions and a retention test. Participants in the self-controlled group were allowed to decide when to receive feedback about their form of movement. In contrast, the yoked group received feedback based on the schedule chosen by the counterparts in the self-controlled group. The results showed that the participants in self-controlled group demonstrated better learning than the yoked group as indicated by the better performance on the throwing form and higher overall accuracy during acquisition and retention phase. As the feedback schedule for both groups were identical, this supported the self-controlled feedback paradigm demonstrating superior learning of motor skills.

The beneficial effect of self-controlled learning was also reported in Wulf & Toole (1999). In their study, participants in the self-controlled and yoked group practiced using physical assistive devices (i.e., ski- poles) when learning in a ski-simulator task. Participants in the self-controlled group were allowed to determine when to use the poles to produce the largest amplitude during practice, while their yoked counterparts had no control on choosing the schedule to use the pole. Although their findings showed that the two groups demonstrated similar performance during training phases, the performance in terms of movement amplitudes in the self-controlled group during retention test was clearly better than their yoked counterparts. The results again provided evidence for the advantages of self-controlled learning condition in motor learning.

There has been no study carried out to investigate the effects of self-controlled feedback on voice motor learning. The present study aims to examine if the benefits of self-controlled practice could be generalized to voice motor learning. It aims to evaluate whether self-controlled feedback paradigm facilitates better learning when compared to external, clinician-controlled feedback paradigm, in the learning of a voice motor task "relaxed phonation". It was hypothesized that participants having control on feedback schedule during training (self-control) would demonstrate better motor learning on relaxed phonation when compared to the yoked group (i.e., the feedback schedule is controlled by the clinician). Results from this study could give insights into the development of training protocol of relaxed phonation. This could also enhance the effectiveness of training and practice strategies in voice motor learning.

METHODS

Participants

Twenty-four vocally healthy individuals (21 females and 3 males) (mean age=28.79 years, SD=6.92, range=20-45 years) were recruited. All of the participants met the following criteria: a) aged between 20 and 45 years old, b) had no history of speech and voice disorders; c) were native Cantonese speaker and could read Chinese characters; and d) had no prior experience with voice training and the use of surface electromyography. Participants were excluded based on the following exclusion criteria a) reported with history of, or present with any form of neurological disorders, and b) reported with history of, or present with respiratory and severe allergy.

Experimental set-up

The surface electromyography (sEMG) system (ADInstruments PowerLab Unit, model ML780 with eight-channels and Dual Bioamp model ML135) and silver-painted electrodes (10mm in diameter) were used. The system was connected to the Labview-based training program. The program displayed the sentence stimuli, analyzed and calculated the root-mean-square (RMS) values of sEMG voltage at the thyrohyoid site in real-time. The Labview program could also adjust the sEMG feedback schedule that being presented in the training for the yoked group.

Abrasive scrub was applied onto the thyrohyoid and oro-facial site of the participants for electrode attachment. Electrodes with electrolyte gel were used to reduce the electrode-skin impedance at the site of attachment. The EMG signals were recorded by the two pairs of electrodes that being attached to the skin at thyrohyoid and oro-facial areas (Figure 1). These two sites were chosen in the present study as they ensure relatively stable EMG signals to be captured during phonation around the head and neck region (Yiu et al., 2005). A pair of electrodes was placed on the oro-facial site, which was 1 cm away from the lip corner on each side. Another pair of electrodes was placed on the thyrohyoid site, which was 0.5 cm away from the midline of thyrohyoid membrane on each side (Figure 2). A dry earth strap was wrapped firmly around the left wrist of the participant.

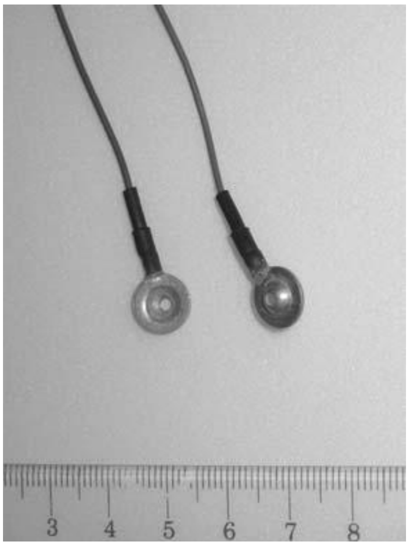

Figure 1. Electrodes for electromyography placement (adapted from Yiu et al., 2005)

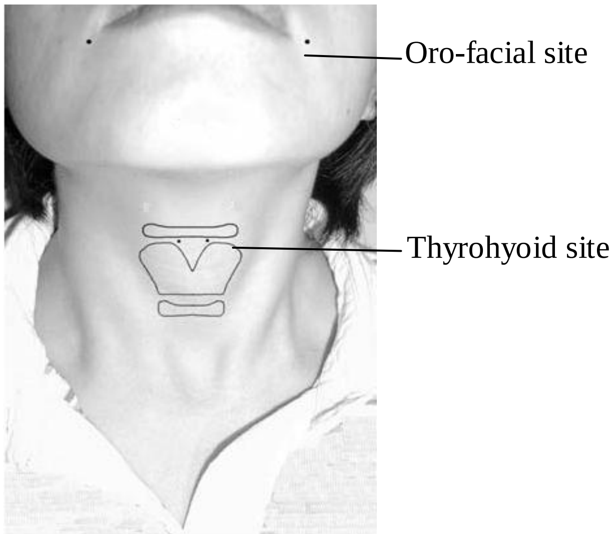

Figure 2. Sites for surface electrode placement (adapted from Yiu et al., 2005)

Training stimuli

Adapted from the word list used by Yiu et al. (2005), the training list comprised 24 target Chinese characters was used in the baseline, training and retention test (See Appendix 1). These characters were chosen in the list of 750 most frequently occurring Chinese characters in Hong Kong (Ho, 1993). They comprised the 19 consonants, 10 diphthongs, 8 vowels and 6 lexical tones in Cantonese. Each target character was embedded in the Cantonese carrier phrase "依個係 (target word)" /ji$_1$ kO$_3$ hai$_5$ (target word)/ (meaning "this one is…") to form a sentence stimuli.

Procedure

Participants attended totally eight training sessions on learning relaxed phonation for twice a week in four consecutive weeks, together with pre-training and post-training assessment session. The training took place individually in a sound-treated booth. Participants sat in comfort on a chair that was measured one meter away from a LCD computer screen with 17 inch large.

"Relaxed phonation" training protocol

Pre-training measurement (session 1). Pre-training assessment was carried out two days before the first training session. To measure the pre-treatment baseline of relaxed phonation, participants had to read aloud four blocks of training stimuli (with 24 sentences in each block) with the most comfortable pitch and loudness using surface electromyography (sEMG). They were also asked to read aloud the Cantonese passage "北風和太陽"(North Wind and the Sun, Appendix II) (Yiu & Chan, 2003). The EMG biofeedback was not provided in the baseline phase. The EMG signals were recorded for later analysis.

Training session (session 2 to session 9). After the pre-training baseline session, participants attended eight sessions of training on relaxed phonation, with two sessions per week. Participants in each group were trained to read aloud four blocks of sentence stimuli. The participants were randomly assigned to one of the two groups: 1) self-controlled group (SELF) and 2) yoked group (YOKED). Each of the participants in the SELF group was matched with another participant in the YOKED group in terms of gender and age. The inclusion of YOKED group was to ensure both the absolute and relative frequency of feedback which is kept the same for both the SELF and YOKED groups. Therefore, any group difference revealed in the retention or transfer test could be attributed to the self-controlled learning effect.

The Labview interface (Figure 3) was introduced to each participant at the start of training session. The root-mean-square (RMS) value of the EMG voltage at thyrohyoid site was calculated and given as biofeedback after reading the sentence. The numerical value was shown at the top of the Labview interface as biofeedback. Participants in both groups were informed that the larger the value indicated more tension in the thyrohyoid area. Both groups were instructed to relax the laryngeal muscle and reduce the value as the ultimate goal. However, the amount and scheduling of feedback were different between the two groups of participants. Participants in the SELF group were encouraged to request feedback when they needed it. Otherwise, no feedback was given. They were explained that no restriction was given on the number of trials they requested for feedback. When the participants in the SELF group requested feedback, they were required to click on the "Display" button shown on the screen after reading aloud the sentence stimuli. The feedback schedule selected for each participant in the SELF group was recorded by the program. Participants in the YOKED group received the same feedback schedule as selected by the self-controlled counterparts. They had no control on the feedback schedule during training (See appendix III).

Post-training measurement (session 9 - session 10). A delayed retention test was carried out one week after the last training session using the four blocks of trained sentence stimuli. Transfer test were also carried out by reading the novel, untrained passage "北風和太陽" (North Wind and the Sun) (Yiu & Chan, 2003). No EMG biofeedback was given and the signals were recorded for further analysis.

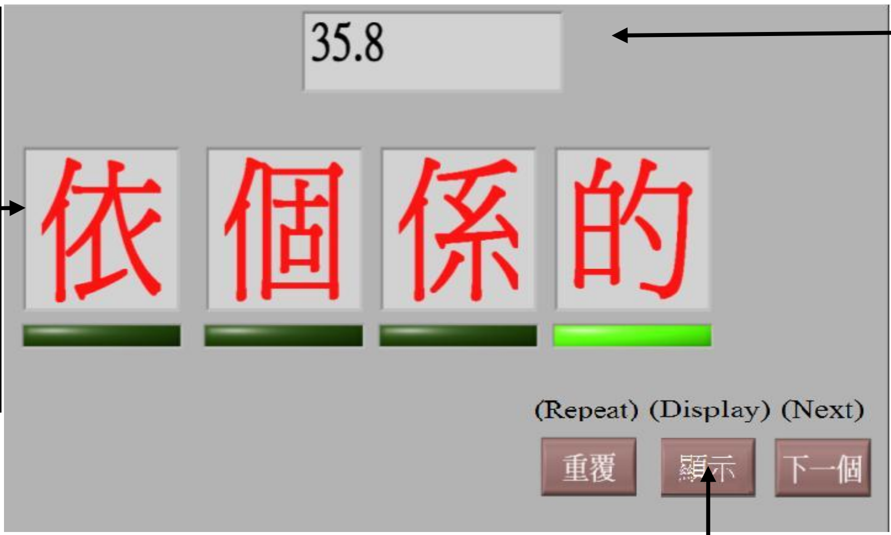

Figure 3. Display of the Labview interface

RESULTS

Effects of learning

To examine the effects of motor learning, the sEMG values measured at both oral and thyroid site were compared across the pre-training and post-training sessions. A three-way within- and between-subjects analysis of variance (ANOVA) was used. The dependent variable was the root-mean-square values of the EMG voltage (the value averaged from each sentence). The within-subject variables included time (10 measurement points across baseline, training and retention tests) and the electrode sites (in orofacial and thyrohyoid site). The between-subject variable included the type of control on feedback schedule (SELF versus YOKED group).

The Mauchly's Test of Sphericity was significant (p=0.0001) which suggested that the data violated the assumption of sphericity. Multivariate statistics results were therefore used for analysis (Pallant, 2005; O'Brien & Kaisser, 1985). To investigate the main effects (time, electrode site, self-control condition) and interaction effects between these independent variables, Multivariate Pillai's Trace test of significance was chosen as it was considered to be a robust test against violation of assumptions in multivariate tests (Coakers & Steed & Price, 2008). The statistical analysis was performed at level of significance p=0.05 in the present study. Table 1 lists the means and standard deviations of the surface EMG voltages for SELF and YOKED group at orofacial and thyrohyoid sites across the 10 measurement phases.

Table 1. Means (and standard deviations) of muscle tension measured in microvolts at the thyrohyoid and orofacial sites for self-controlled (SELF) and yoked (YOKED) group across the 10 measurement points.

	Baseline	**Training**								**Delayed Retention**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
SELF-CONTROLLED GROUP										
Pooled data	**46.02**	**42.42**	**42.71**	**41.69**	**44.03**	**40.66**	**42.76**	**42.29**	**39.78**	**38.74**
TH	35.64	35.99	32.57	31.73	34.95	31.06	32.86	31.60	32.35	30.82
	(8.76)	(9.14)	(10.08)	(8.94)	(10.32)	(7.48)	(8.30)	(9.95)	(9.57)	(6.28)
OF	56.40	48.84	52.84	51.64	53.11	50.26	52.65	52.98	47.21	46.66
	(18.26)	(16.19)	(19.13)	(18.72)	(14.82)	(15.69)	(15.95)	(25.66)	(16.47)	(4.83)
YOKED GROUP										
Pooled data	**37.26**	**33.18**	**33.06**	**37.12**	**34.55**	**34.27**	**34.36**	**32.03**	**33.39**	**32.61**
TH	32.06	30.06	28.91	28.91	28.75	28.29	29.03	27.88	28.42	28.00
	(8.58)	(5.99)	(7.14)	(5.57)	(4.26)	(7.26)	(7.80)	(7.17)	(6.81)	(4.84)
OF	42.46	36.29	37.2	45.33	40.34	40.24	39.69	36.18	38.35	37.22
	(17.52)	(16.35)	(18.11)	(25.28)	(16.73)	(18.42)	(17.89)	(16.71)	(17.15)	(15.87)

Note. TH = Thyrohyoid site; OF = Orofacial site.

Time effect. The Pillai's Trace ANOVA revealed the main effect of time was significant [$F(9, 14)=2.84$, $p=0.04$]. Pooled data in Table 1 revealed a reduction of sEMG voltage across baselines, training and retention tests in both SELF and YOKED group.

Group effect. The overall main effect of group was not significant [$F(1, 22)=3.89$, $p>0.05$]. Statistical analysis failed to demonstrate better learning for SELF group across the 10 measurement points.

Site effect. There was significant main effect of site [$F(1, 22)=25.59$, $p= 0.001$]. The sEMG voltage at thyrohyoid site was significantly lower than orofacial site.

Interaction effects. None of the interaction effects were significant (time by group interaction, $F=1.48$, $p>0.05$; site by group interaction, $F=2.00$, $p>0.05$; time by site interaction, $F=2.52$, $p>0.05$, time by site by group interaction, $F=1.00$, $p>0.05$).

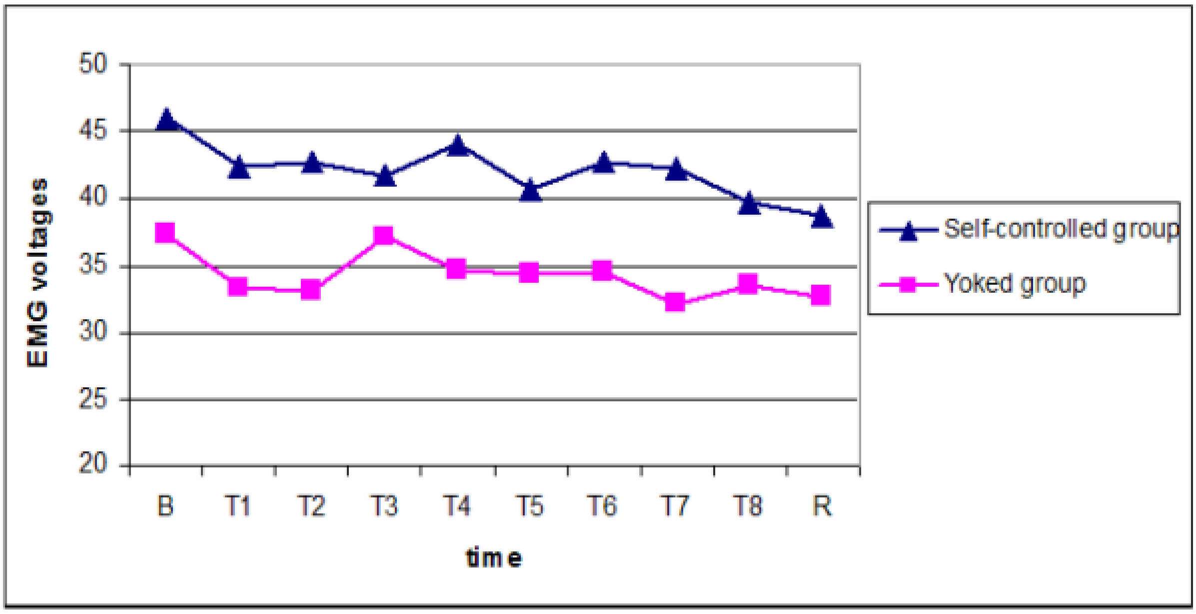

Figure 4. Change of muscle tensions across ten measurement points for the SELF and YOKED group

Feedback Frequency

Table 2 showed the average percentage of sEMG biofeedback the participants in SELF group requested. The EMG biofeedback was requested on an average of 69.21% of the total training trials.

Table 2. Summary of feedback requested by the 12 participants in the self-controlled group (SELF) across the eight-training sessions.

	Training session							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total number of feedback (N=1152)	786	843	887	804	781	764	746	767
Average number of feedback by each participant	65.50	70.25	73.92	67.00	65.08	63.67	62.17	63.92
Standard Deviation	34.01	34.39	31.94	42.28	41.59	40.77	40.59	41.85
Range	2-96	3-96	11-96	1-96	0-96	0-96	0-96	0-96
Relative frequency *	68.23	73.18	77.00	69.79	67.80	66.32	64.76	66.58

*: total number of feedback requested / total number of training trials (N=1152)

Generalization effects

To examine the effects of generalization, the changes in sEMG voltage in reading the untrained passage “北風和太陽” (North Wind and the Sun) between the pre-training measurement and transfer test were compared for each of the SELF and YOKED group. A three-way within- and between-subjects analysis of variance (ANOVA) was employed to investigate the generalization effect. The dependent variable was the root-mean-square values of the EMG voltage (the value averaged from each sentence). The within-subject independent variables included time (two measurement points in baseline and transfer tests) and the electrode sites (in orofacial and thyrohyoid site). The between-subject variables included the type of control on feedback schedule (SELF versus YOKED group). Table 3 lists the pooled data of the sEMG voltages in transfer test for the two groups.

Table 3. Means (and standard deviations) of muscle tension measured in microvolts at the thyrohyoid and orofacial sites for self-controlled(SELF) and yoked(YOKED) group across the two measurement points for reading untrained paragraph.

	Baseline	**Delayed Retention**
SELF-CONTROLLED GROUP		
Pooled data	**21.05**	**20.51**
Thyrohyoid site	17.21 (4.49)	16.31 (3.86)
Orofacial site	24.89 (6.13)	24.71(6.77)
YOKED GROUP		
Pooled data	**20.93**	**19.67**
Thyrohyoid site	15.85 (4.12)	15.14 (3.95)
Oro-facial site	26.00 (7.63)	24.20 (7.55)

Time effect. The main effect of time was significant [F(1, 22)=4.33 , *p*=0.05]. The statistical analysis revealed a significant improvement in muscle relaxation was observed at both sites. Generalization of laryngeal relaxation to reading untrained passage in the transfer test was indicated. Figure 5 shows the EMG voltages changes measured across the pre-training and at transfer test for the two groups.

Group effect. The main effect of group was not significant [F(1, 22)=0.056 , *p*=0.82]. The SELF and YOKED group had similar performance in generalizing laryngeal relaxation to reading paragraph.

Site effect. There was significant main effect of site [F(1, 22)=64.81, *p*=0.001]. The sEMG voltage at thyroid site was significantly lower than orofacial site in generalization task.

<u>Interaction effect.</u> None of the other interaction effects reached a significant level at p=0.05 (time by group interaction, F=0.71 , p=0.41 ; site by group interaction, F=0.51 , p=0.48 ; time by site interaction, F=0.085 , p=0.77 , time by site by group interaction, F=2.11 , p=0.16).

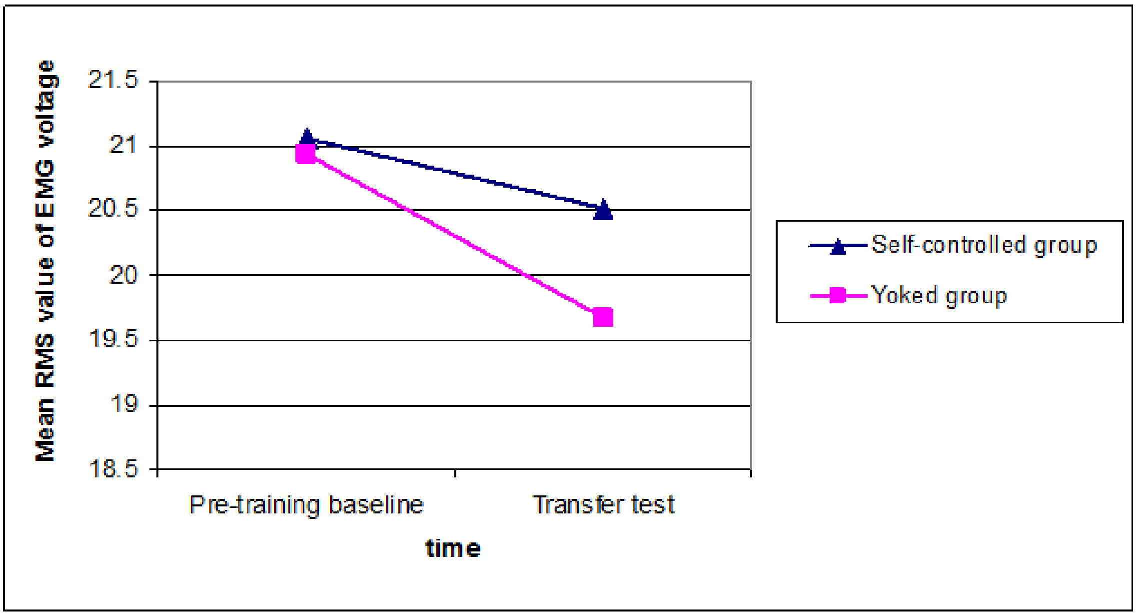

Figure 5. Change of muscle tensions across two measurement time points for SELF and YOKED group

DISCUSSION

The aim of the present study was to examine the effects of self-controlled feedback paradigm on motor learning of relaxed phonation in vocally healthy individuals. It was hypothesized that learning with self-controlled feedback paradigm demonstrated better learning effect on relaxed phonation than the YOKED group (i.e., with clinician-controlled feedback paradigm). However, the results did not support the hypothesis. The performance in the SELF group was not differed from the YOKED group in the learning of relaxed phonation task in both acquisition and retention phase. Results suggested that participants with more controlled over the feedback schedule did not benefit on learning relaxed phonation than the group with prescribed feedback schedule. The present findings appeared to contradict findings from previous literature results that participants with self-controlled learning demonstrated significant better performance in the retention phase (Janelle et al., 1995; Chiviacowsky & Wulf, 2002). It was possible that the relatively high frequency of feedback requested by participants in the SELF group might have imposed a detrimental effect on the self-controlled motor learning. The guidance hypothesis might have accounted for the absence of self-controlled learning effect.

The possible self-controlled learning effect might be degraded by the relatively high frequency of feedback requested by participants in the SELF group in the present study. In some of the preceding studies demonstrated the effectiveness of self-controlled practice in motor learning, the amount of feedback requested by participants was relatively low. For example, participants requested an average feedback frequency about the form of movement with 7% in a ball tossing task (Janelle et al., 1995) and with an average of 11% in a throwing ball task using non-dominant hand (Janelle et al., 1997). In the present study, the participants in the SELF group requested relatively high frequency of feedback across the training sessions, with an average of 69.21% of the total training trials (see Table 2).

To explain the possible detrimental effects of frequent feedback on the self-controlled learning effect, the argument was made based on the guidance hypothesis (Salmoni, Schmidt, & Walter, 1984). According to the guidance hypothesis, frequent augmented feedback guides the learners to perform correct movement during the phase of skill acquisition (Wulf & Schmidt, 1989). However, it also imposed negative effects on motor learning when the feedback was withdrawn in retention test (Schmidt & Lee, 1999). Steinhauer and Grayhack (2000) supported that the guidance hypothesis could be applied to the area of voice motor learning as their study result revealed frequent feedback degraded the learning effect in a vowel nasalization task. Possible explanations suggested that frequent feedback limited the cognitive effort of the participants in learning of the relaxed phonation task. The participants became dependent on the feedback when it was frequently shown in the training. This might desensitize the participants in detecting error and reduced their opportunities in modifying learning strategies in skill learning.

By considering the negative effects of frequent feedback on motor skill learning, it was suggested that these effects could have reduced the advantages of self-controlled learning in the present study. The motivational effect (Chiviacowsky & Wulf, 2002) and deeper cognitive processing (McCombs, 1989) have been proposed to explain the self-controlled learning effects. However, the frequent feedback requested in the present study reduced the cognitive processing of the intrinsic feedback regarding the laryngeal muscle activity in learning relaxed phonation. The over-reliance of feedback also interfered with the development of deeper and effective information processing of information regarding the movement mechanism in self-controlled learning process (Janelle, et al., 1995; McCombs, 1989). It further reduced the opportunities for the participants to explore different movement strategies to achieve laryngeal muscle relaxation in the self-controlled learning condition. Therefore, it would be interested to investigate if the amount of self-controlled feedback affects the learning effectiveness of self-controlled learning in the relaxed phonation task. This could contribute to better understanding on the design of more effective self-controlled training protocol in learning relaxed phonation.

Another possible explanation for the absence of self-controlled learning effect might be related to the need of learners when requesting feedback. According to Chiviacowsky and Wulf (2002), the self-controlled learning condition was beneficial to learning as it corresponded more to the learner's need. Among the twelve participants in the SELF group, eight of the participants tended to request at least 80% of feedback throughout the eight training sessions. The high frequency of feedback requested by the vocally healthy individuals raised concern on whether they took the advantages of self-controlled learning and requested feedback when they actually need it. If they tend to request feedback regardless of their need in learning, the learning effect might be suppressed. In contrast to vocally healthy individuals, dysphonic participants might have relatively higher motivation to learn relaxed phonation. This gives insights to replicate the present study in a group of dysphonic participants as the self-controlled learning benefit might be shown better in study with dysphonic individuals.

Although the self-controlled learning effect was not revealed in the present study, it further supported the results in Fong (2009) that the effectiveness of voice relaxation training in vocally healthy population. Pooled data in Table 1 indicated that participants in both groups demonstrated significant reduction of muscle tension at thyrohyoid and orofacial sites over baseline, training and transfer test. The performance maintained in transfer test further provided evidence to support the existence of true learning effects using EMG biofeedback in voice relaxation training. Furthermore, the results indicated that the participants in both SELF and YOKED group were able to generalize the muscle relaxation skills learnt in relaxed phonation task to reading untrained passage. Evidence in transfer of learning was suggested as participants were able to apply previously learnt skills in the relaxed phonation to a new context (Magill, 1998). Although statistical analysis revealed significant generalization effect of time, caution should also be taken in interpreting the result as there was only slight variation in sEMG voltage at both sites at pre-training baseline and transfer test.

However, the performance of the SELF and YOKED group in the generalization tasks with untrained passage was similar. No generalization effect was particularly revealed in the SELF group with the self-controlled feedback paradigm in training. It was unsurprising that the generalization effect of the present study did not agree with the literatures in the field that the SELF group demonstrated both better learning and generalization of learnt skills to trained and novel task in their studies (Chiviacowsky & Wulf, 2002). The result could be explained by the dependency effect of high frequency feedback during acquisition in the SELF group, that nullify any potentially robust learning and generalization effect of learning with self-controlled feedback paradigm.

Limitation of the present study and future research directions

Inclusion of dysphonic individuals

In the present study, all the participants recruited were vocally healthy. They may find the relaxed phonation task comparatively less-challenging and easy to learn. The benefits of self-controlled learning were therefore not reflected. To further improve in the future research, dysphonic population should be targeted to examine the effects of self-controlled learning on voice motor learning.

Larger sample size

Only 24 participants (12 participants in the self-controlled and yoked group) were recruited in this study. The sample size may not be large enough to demonstrate the effects of self-controlled learning. A larger sample size should be targeted in the future study to evaluate the performance difference between the two groups.

Task design

In the present study, the participants tend to request high frequency of feedback. This may impose detrimental effects on learning benefits of training with self-controlled feedback paradigm. The motor learning effect was influenced by the instruction given to the participants (Kisner & Colby, 2002). Therefore, it was suggested to modify the instruction of the present “relaxed phonation” training protocol to encourage participants request feedback only when they need it. This modification could enhance the learning benefits of self-controlled learning.

CONCLUSION AND CLINICAL IMPLICATION

The present study examined the effects of self-controlled feedback in voice motor learning. Significant difference in learning and generalization was not shown between participants provided with self-controlled and clinician-controlled feedback paradigm. The results suggested that there was no clear evidence to support the self-controlled feedback paradigm was beneficial to learning. However, it supported the effectiveness of sEMG biofeedback in learning of relaxation phonation task. It is recommended to replicate the study in dysphonic population to optimize the effectiveness of self-controlled learning of relaxed phonation. Further studies with modification of the instruction of training were recommended to investigate the effect of self-controlled feedback frequency in motor learning of relaxed phonation.

ACKNOWLEDGEMENT

I would like to thank my dissertation supervisor, Dr. Estella Ma, for her guidance, valuable comments and support throughout the study. I thank Mr. Ronald Tse for his technical support on the Labview Programme. I would acknowledge Miss. Amy Wong and Miss Irene Fong for their generous advices on the data collection procedures. I would also like to thank Miss Maria Yeung for her assistance in subject recruitment. Gratitude must be expressed to all the subjects for their generous participation in this study. Lastly, I would like to express my sincere gratitude to my family, friends and fellow classmates for their endless patience and support.

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Appendix: I

The 24 Chinese characters used in the training phase.

Target stimuli		IPA Symbol	Order of frequency based on Ho (1993)	Target stimuli		IPA symbol	Order of frequency based on Ho (1993)
1	的	tik_{55}	1	13	情	$ts^{h}iN_{21}$	176
2	不	pAt_{55}	4	14	每	mui_{23}	196
3	有	jAu_{23}	5	15	月	jyt_{22}	216
4	在	$tsOi_{22}$	6	16	教	kau_{33}	231
5	了	liu_{23}	7	17	老	lou_{23}	239
6	我	NO_{23}	9	18	片	$p^{h}in_{33}$	246
7	為	wAi_{21}	10	19	給	$k^{h}Ap_{55}$	259
8	這	tsE_{35}	11	20	男	nam_{21}	328
9	水	sJy_{35}	75	21	父	fu_{22}	332
10	起	hei_{35}	104	22	卻	$k^{h}Jk_{33}$	461
11	解	kai_{35}	117	23	談	$t^{h}am_{21}$	464
12	果	kwO_{35}	171	24	群	$kw^{h}An_{21}$	716

The selection of target words was based on its order of frequency (Ho, 1993).

Appendix II.

Novel stimuli: The reading passage in the pre-training baseline and transfer test

北風和太陽

有一天，北風和太陽爭論說，到底是誰的本領高。當他們爭論的時候，有一個人經過，他正穿著一件厚厚的黑色外衣。

因此他們便說，看看誰能脫去那人身上厚厚的外衣。北風首先狠狠的吹，可是他越吹得狠，那個人就越把外衣拉緊。所以，北風就放棄了。

一會兒後，太陽出來了，那個人很快便將外衣脫下來，北風只好承認太陽較他厲害。

The passage was “北風和太陽”(North Wind and the Sun) (Yiu & Chan, 2003).

Appendix III.
Instructions for the experiment

Self-controlled group: Instructions on self-controlled feedback paradigm in learning of relaxed phonation task.

“A sentence will be displayed on the computer screen in every trial. You have to read aloud the sentence with a stead speed according to the green indicator under each word of the sentence. After your production, you are allowed to request a number index to be shown on the top of the screen according whenever necessary. The number reflects your laryngeal muscle tension during reading of sentence. The greater the number, the tenser your laryngeal muscle is. Throughout the relaxed phonation training, you are encouraged to request for the number whenever you need it. There is no restriction on the number of trials that you request for the number. You should aim at reducing this number throughout the training. ”

「稍後螢幕會每次顯示一句句子，你需依照每個字下的綠色燈提示，把句子均速地讀出來便可。你讀完句子後，可以跟據自己的需要要求在瑩光幕的上方顯示一個數字，它代表了你讀句子時頸部肌肉的收緊程度，數字越高，表示你頸部肌肉收得越緊。在整個發聲練習中，你可隨時要求顯示數字，次數不限。你的目標是把這個數字降低。」

Yoked group: Instructions on externally-controlled feedback paradigm in learning of relaxed phonation task.

“A sentence will be displayed on the computer screen in every trial. You have to read aloud the sentence with a stead speed according to the green indicator under each word of the sentence. After your production, a number index will be shown on the top of the screen according to the preset sequence. The number reflects your laryngeal muscle tension during reading of sentence. The greater the number, the tenser your laryngeal muscle is. You should aim at reducing this number throughout the training. ”

「稍後螢幕會每次顯示一句句子，你需依照每個字下的綠色燈提示，把句子均速地讀出來便可。你讀完句子後，瑩光幕的上方會依照預的時間顯示一個數字，它代表了你讀句子時頸部肌肉的收緊程度，數字越高，表示你頸部肌肉收得越緊。你的目標是把這個數字降低。」